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GB 0686530 A GB 0677824 A US 4253523 A
US 4191265 A US 4140188 A

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INT CL[6] E21B , F42B , F42D
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(54) Shaped charges

(57) An apparatus for retaining shaped charges (14) using a foam core (10) having charge carrying recesses (12) and constructed from a single piece or from multiple sections. Shaped charges (14) can be inserted into the foam core recesses (12) so that the shaped charges (14) are proximate to a detonator cord (16) positioned inside or outside of the foam core (10). The foam core assembly holding the detonator cord (16) and shaped charges (14) is inserted into a housing such as a cylindrical tubing to construct a perforating gun. A seal isolates the shaped charges from pressurized well fluids. The housing can be attached to a firing head and lowered to the desired depth in a well casing. Additional foam sections can be added to modify the number and orientation of the shaped charges. The apparatus is particularly useful with thin housing material and can substantially reduce the manufacturing cost of perforating guns.

Fig. 1

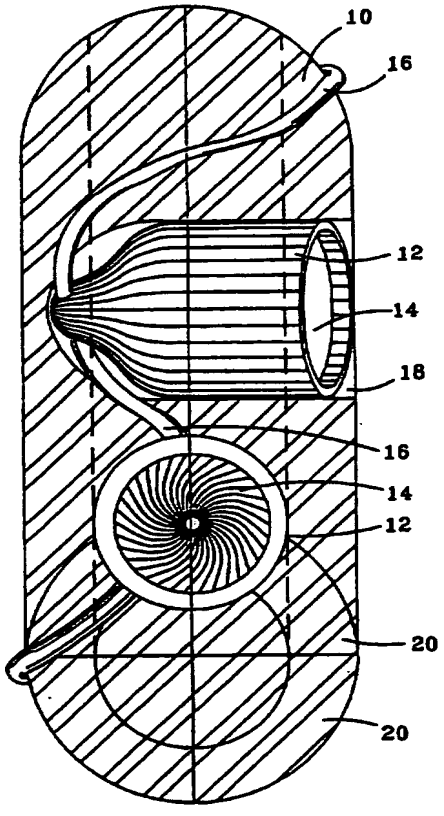

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Fig. 1

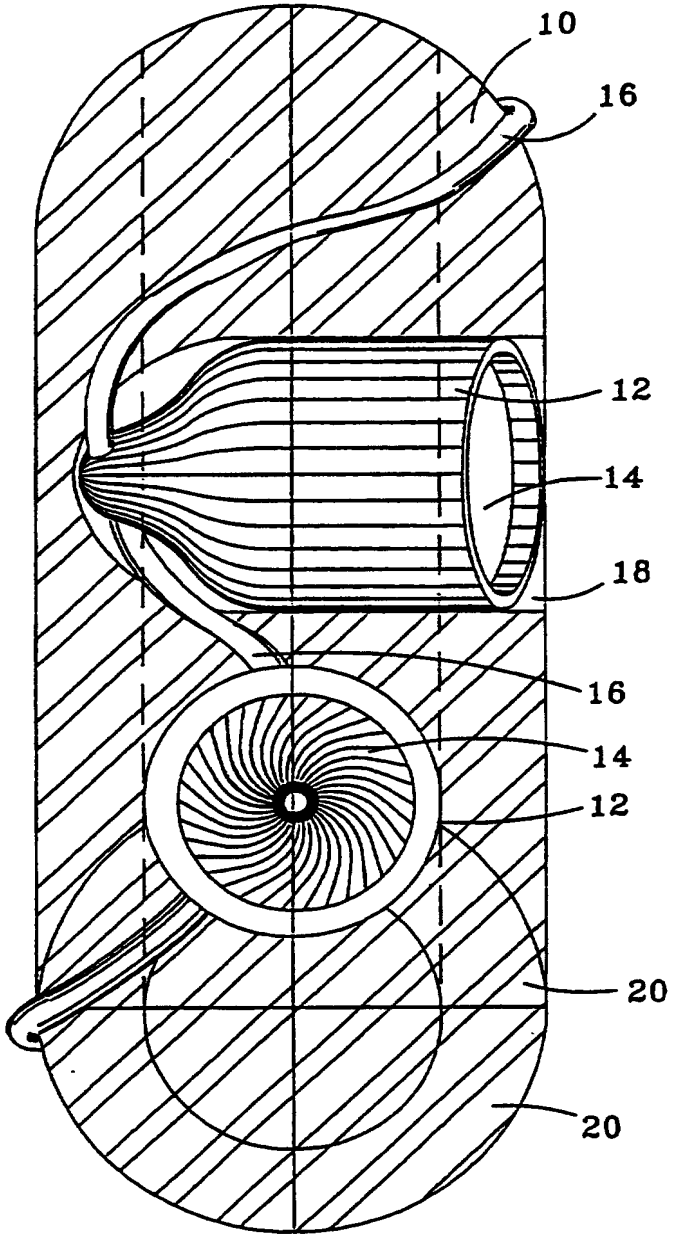


Fig. 2

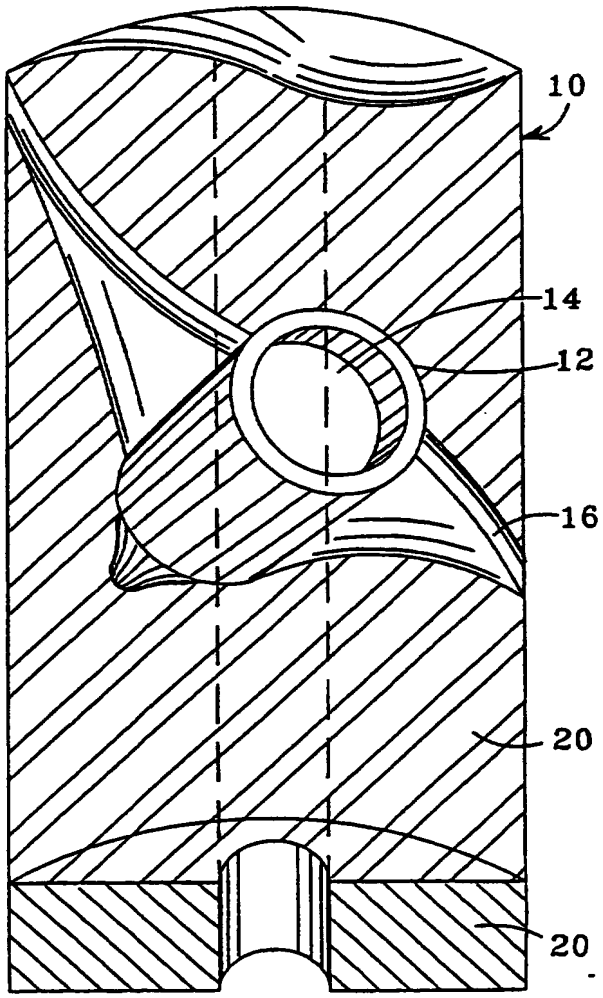


Fig. 3

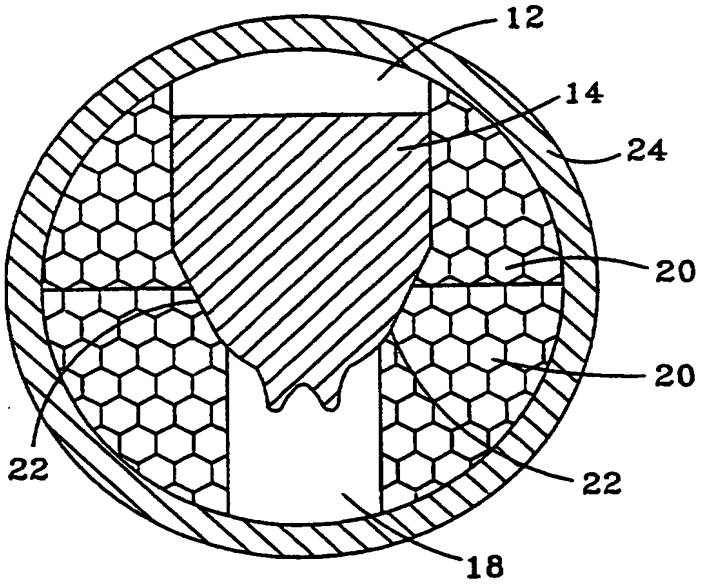


Fig. 4

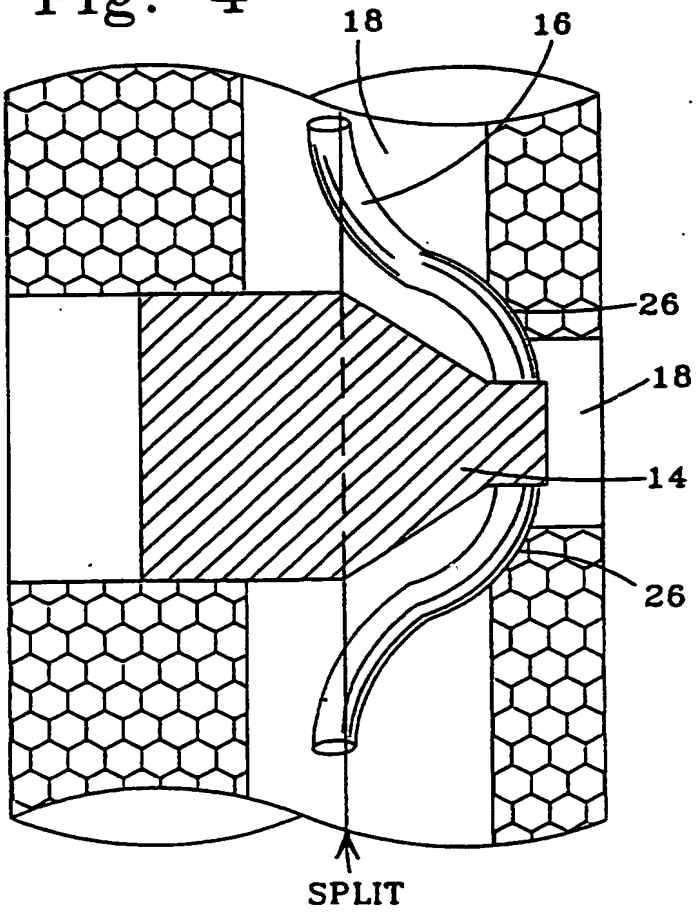


Fig. 5

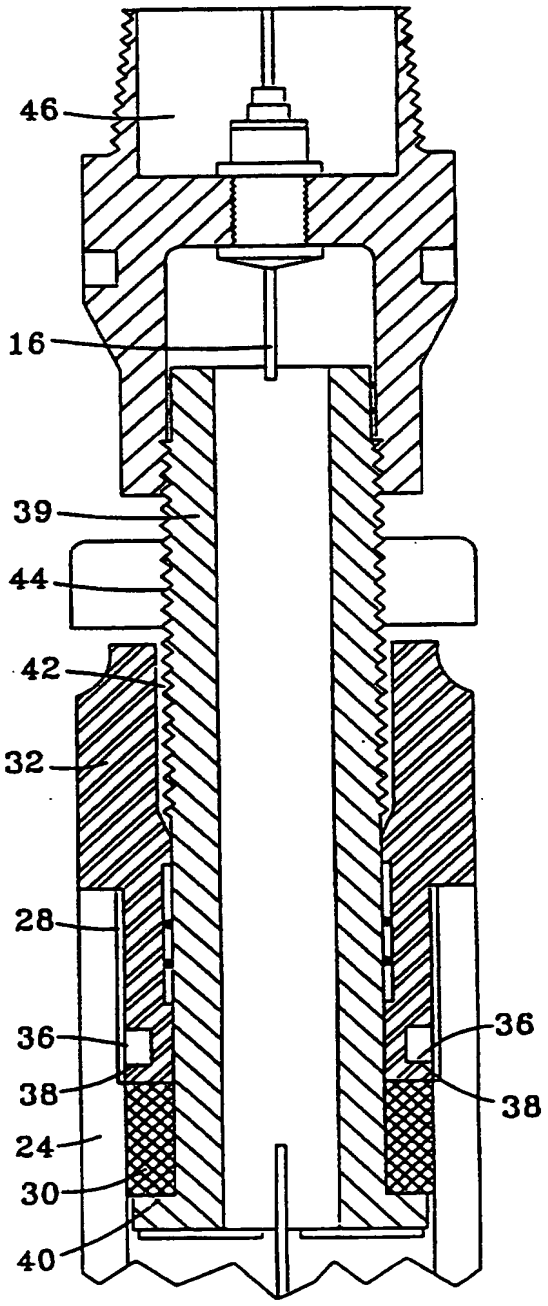


Fig. 6

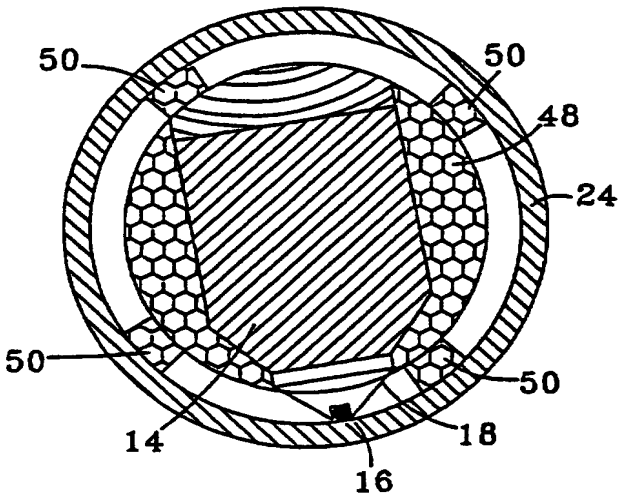


Fig. 8

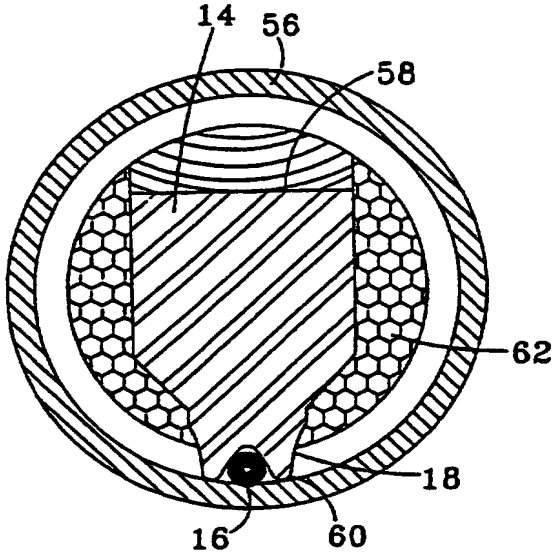


Fig. 7

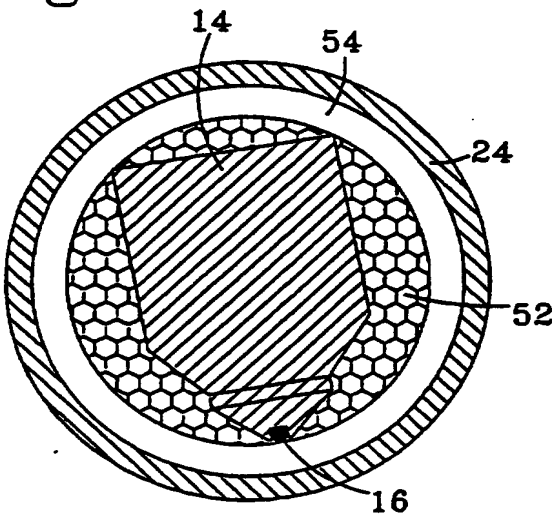
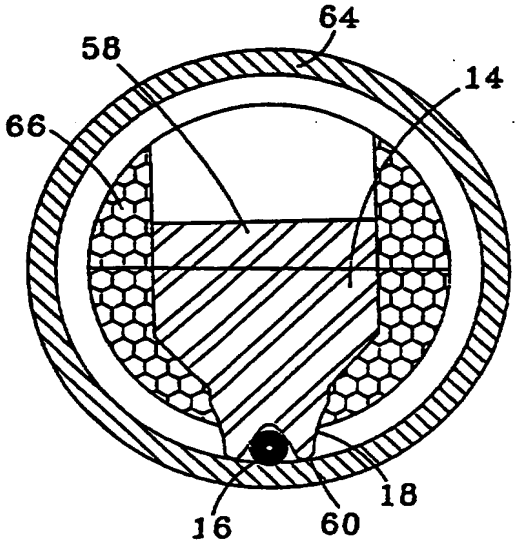


Fig. 9



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SHAPED CHARGES

The present invention relates to shaped charges, for example for perforating casing in hydrocarbon producing wells.

A well casing is typically installed in a borehole drilled into subsurface geological formations. The well casing prevents uncontrolled migration of subsurface fluids between different well zones and provides a conduit for installing production tubing in the well. The well casing also facilitates the running and installation of production tools in the well.

To produce hydrocarbon fluids from a subsurface formation, the well casing can be punctured by multiple shaped charges in a perforating gun. The perforating gun includes a firing head which is actuated to detonate a primary explosive and to ignite a booster charge connected to a primer or detonator cord. The detonator cord transmits a detonation wave to each shaped charge. Booster charges within each shaped charge activate explosive material within the charges which collapse the shaped charge liner. Each liner generates a high velocity jet for penetrating the well casing and the surrounding geological formations. Such jets perforate the well casing and establish a flow path for the hydrocarbon fluids from the subsurface geological formations to the interior of the well casing. In a well having multiple production zones, packers can isolate selected zones of the well casing, and production tubing transports the hydrocarbon fluids from such zones to the well surface.

Perforating gun firing heads can be actuated by mechanical, hydraulic or electrical mechanisms. Multiple shaped charges are closely positioned within perforating guns to maximize the number of well casing perforations reacted within the well casing. In one type of perforating gun, the shaped charges are

fastened to a metallic string and are lowered into the borehole. In another type of perforating gun, the shaped charges are isolated from pressurized well fluids by a metallic housing having threaded ports machines into the housing wall. Fittings are rotated into each port and a shaped charge is positioned to fire through each port. Although such perforating guns can be used for multiple wells, the gun housings require heavy metal tubulars and expensive machining modifications.

Various efforts have been made to reduce the cost of perforating guns without affecting the integrity of the shaped charges. For example, perforating guns have been constructed from thin wall tubular housing sections attached with expandable slip systems. Shaped charges are retained within the housing sections with metal spiders, brackets, metal strips, and other fastening systems to orient the shaped charges in a fixed position relative to the gun housing interior. Such fastening systems require extensive labour to install the shaped charges.

Additionally, components of such fastening systems are destroyed by the detonation of the shaped charges and leave residue within the well casing. This perforating gun residue is undesirable and can interfere with well producing operations.

Accordingly, a shaped charge retainer system that retains shaped charges in a selected orientation and that isolates the shaped charges from pressurized fluids is desirable. The retainer should ideally be able to withstand the well conditions without failure, to retain the shaped charges in a selected position, and to be relatively easy to manufacture and use.

Various aspects of the present invention are exemplified by the attached claims.

Another aspect of the present invention provides

an apparatus and method for retaining a shaped charge, ignitable by a detonator cord, within a housing which can be lowered into a well. The apparatus includes a foam core insertable within the housing. A recess in the foam core retains the shaped charge. A hole in the foam core permits engagement between the detonator cord and the shaped charge.

In other embodiments of the invention, the foam core can be formed in two adjacent sections to facilitate placement of the detonator cord, and an additional foam core can be positioned adjacent to the first foam core to increase the number of shaped charges within the housing. The exterior surface of the foam core can substantially conform to the inner wall surface of the housing or can be configured to stand off from such inner wall surface with ribs or other protrusions. A seal can be positioned within an open end of the housing to isolate the shaped charges from the well casing interior.

A method embodying the invention may be practiced by positioning a foam core adjacent the housing, by placing a detonator cord proximate to the foam core, by inserting a shaped charge in a recess within the foam core, and by inserting the foam core, detonator cord and shaped charge into the open end of the housing.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 is an elevation view of a foam core section showing shaped charge recesses oriented at a ninety degree relative angle;

Figure 2 is a schematic view of a shaped charge recess oriented within two adjacent foam core sections;

Figure 3 is an end view of a shaped charge within the recess of a foam core;

Figure 4 is a side view of a shaped charge within the recess of a foam core;

Figure 5 illustrates a seal and packing mechanism for closing an open end of a cylindrical housing;

Figure 6 illustrates ribs for centering a foam core in a cylindrical housing;

Figure 7 illustrates an embodiment of the present invention wherein the front surface of a shaped charge positions the foam core within a cylindrical housing;

Figure 8 illustrates an embodiment of the present invention wherein the back surface of a shaped charge positions the foam core within a cylindrical housing; and

Figure 9 illustrates an embodiment of the present invention wherein the foam core positions a shaped charge with a stand off relative to the inner wall of a cylindrical housting.

Referring to Figure 1, a foam core 10 has recesses 12 for containing shaped charges 14. A detonator cord 16 is engaged with shaped charges 14 and is positioned within hole 18 of foam core 10. The foam core 10 is illustrated as having a substantially cylindrical exterior surface which can conform to the interior wall surface of a cylindrical housing as described more thoroughly below. Although the exterior surface of the foam core 10 can be substantially cylindrical as shown in Figure 1, such surface could be indented or formed in different geometrical shapes sufficient to be inserted within the housing.

Although the foam core 10 could be constructed as a single piece, one alternative embodiment of foam core 10 is shown in Figure 1 wherein two or more foam core sections 20 are positioned adjacent to the other to create the foam core 10. By constructing the foam core 10 with two or more core sections 20, the installation of a detonator cord 16 and of shaped charges 14 within

the foam core 10 can be facilitated. The contact between foam core sections 20 can exist along a substantially flat plane parallel to a longitudinal axis of the housing illustrated in Figure 1, or could comprise other shapes.

A hold 18 can extend through one or both of core sections 20 to retain the detonator cord 16 inside or outside of the foam core 10. Each hole 18 of a plurality of holes 18 can define a cavity, an opening, perforation, void, gap or aperture in the foam core 10 sufficient to permit engagement between shaped charges 14 and the detonator cord 16. The hole 18 can be substantially located within the foam core 10 to retain the detonator cord 16 within the foam core 10. For alternative embodiments of the invention wherein the detonator cord 16 is positioned outside of the foam core 10, the hole 18 can comprise an opening adjacent shaped charge 14 for permitting engagement between the shaped charge 14 and the detonator cord 16. The hole 18 can be configured to permit a portion of the shaped charge 14 to extend through the hole 18 so that the shaped charge 14 protrudes outside of the foam core 10.

Each core section 20 can be a mirror image of the other core section 20. Alternatively, each core section can be constructed with different shapes sufficient to facilitate the placement of the detonator cord 16 and the shaped charge 14. As shown in Figure 2, one orientation of the recess 12 is illustrated before the insertion of the shaped charge 14. Figure 2 illustrates another feature in which the lengths of core sections 20 are offset so that additional core sections 20 can be added to extend the total length of the foam core 10. Such offset of core sections 20 can be designed to maintain the desired longitudinal spacing between shaped charges 14 on adjacent core sections 20. In this fashion, the shot pattern for a

plurality of shaped charges 14 can be controlled.

The foam core 10 can be fabricated from polyethylene, styrofoam, plastic, pulp material, or any organic, inorganic, or metallic material having the desired characteristics. The term "foam" as used herein includes without limitation all of these different materials which are suitable for forming or constructing the foam core 10. The foam core 10 can be formed as a composite of different materials or can be homogeneous in composition. In a preferred embodiment of the invention, the foam core 10 is formed with a material which is pulverized or disintegrated upon the detonation of shaped charges 14 so that discernable residue does not remain within the wellbore after the perforating gun is fired.

Referring to Figure 3, the core sections 20 are semicircular and are illustrated as having substantially flat surfaces in contact with the other. The contact between the core sections 20 does not have to be planar but could exist along certain contact points. Additionally, such contact could be along a curved plane or other defined shaped to establish the desired orientation of each core section 20 relative to the other.

The dimensions of the recess 12 are selected to provide a snug fit with shaped charge 14. In one embodiment of the invention, the diameter of the recess 12 can be slightly smaller than the outside dimension of the shaped charge 14. Because of the compressibility of the foam forming core sections 20, the shaped charge 14 can be inserted into the recess 12 so that the restoring force provided by the foam acts against the shaped charge 14 to resist movement of the shaped charge 14.

The recess 12 can be shaped in different ways to accomplish the desired contact with the shaped charge

14. For example, the recess 12 can have beveled shoulders 22 which mate against the shaped charge 14. In this embodiment, the shoulders 22 position the shaped charge 14 at a selected position relative to the exterior surface of the foam core 10. In one embodiment of the invention as illustrated in Figure 3 the recess 12 can extend through the foam core 10 so that the shaped charge 14 is accessible from two different sides. In this embodiment, the liner side off the shaped charge 14 is open to cylindrical housting 24, and the booster side of the shaped charge 14 is accessible to facilitate the engagement of the detonator cord 16 with the shaped charge 14.

As shown in Figure 4, the hole 18 can extend through the foam core 10 to permit the installation of the detonator cord 16 within the foam core 10. In one embodiment of the invention, the foam core 10 can be formed with contact points 26 for contacting the detonator cord 16 and for providing a friction contact retaining the detonator cord 16 in a fixed position relative to the shaped charge 14. This configuration provides a similar function to that provided by the shoulders 22 in Figure 3.

The configuration of embodiments of the invention permits the housing 24 to be formed or constructed from a material having a thickness less than conventional perforating gun housings. Consequently, the weight and cost of the housting 24 is less than conventional housings. The housing 24 may be too thin to permit the conventional use of packing slips or mechanical threads to provide attachment with a firing head. Referring to Figure 5, the housing 24 has an open end 28 closed with a seal 30. The seal 30 comprises a packing material or sealing element which can be energized or set with an anchor 32 and a mandrel 34.

The anchor 32 is attached to the housing 24 with

pins or bolts 36 inserted through apertures 38 in the wall of the housing 24. The pins 36 prevent longitudinal or rotational movement between the anchor 32 and the housing 24. The mandrel 34 has a flange surface 40 for engaging the seal 30, and has threads 42 which are engageable with a threadform in a nut 44. As the nut 44 is rotated, the nut 44 contacts the anchor 32 and draws the flange surface 40 toward the anchor 32 to compress the seal 30. Such compression urges the seal 30 into contact with the inner wall surface of the housing 24. The mandrel 34 can also have a threaded engagement with the firing head 46 so that a mechanical connection is provided between the housing 24 and the firing head 46. This mechanical connection is provided without requiring substantial machining of the cylindrical housing 24.

As shown in Figure 5, the detonator cord 16 extends from the firing head 46 through the seal 30 into the foam core 10. The seal 30 isolates the foam core 10 and the encapsulated shaped charges 14 from well fluids and from the pressure in the well bore. Although one configuration of the seal 30, the anchor 32 and the mandrel 34 is described, other different sealing systems can accomplish the functional result accomplished by the seal 30 and the mechanical system shown for energizing the seal 30.

Figure 6 illustrates an alternative foam core 48 having protrusions or ribs 50 extending outwardly from the centre body of the foam core 48. The ribs 50 contact the inner wall of the housing 24 and resist longitudinal and rotational movement of the foam core 48 relative to the housing 24. The ribs 24 also cushion the shaped charges 14 from impacts acting against housing 24.

Figure 7 shows an alternative embodiment of the invention wherein the shaped charge 14 is positioned

within a foam core 52. As shown, the foam core 52 is separated from the housing 24 by an annular gap 54 which facilitates the insertation of the foam core 52 into the housing 24. The detonator cord 16 is protected within the hole 18 which is recessed within the exterior surface of the foam core 52.

Referring to Figure 8, the shaped charge 14 is positioned within a smaller diameter housing 56 so that the offset distance from the front surface 58 of the shaped charge 14 is relatively close to the inner surface of the housing 56. A back edge 60 of shaped charge 14 contacts the inner surface of the housing 56, so that a combination of shaped charges oriented at ninety degrees, one hundred eighty degrees, or other orientations cooperate to centre the foam core 62 within the housing 56.

Figure 56 illustrates a similar configuration for the shaped charge 14 in a larger housing 64, wherein there is a greater offset between a front surface 58 of the shaped charge 14 and the inner surface of the housing 64. As previously described, additional shaped charges 14 can be oriented to centre the foam core 66 within the housing 64.

Although the detonator cord 16 can be positioned within a hole or holes 18 within the foam cores illustrated herein, the detonator cord 16 can also be run on the outside surface of the foam cores as shown in Figures 6, 8 and 9. This position can facilitate the engagement of the detonator cord 16 with the shaped charges 14 to reduce the installation time necessary to assemble a perforating gun. As previously described, the hole 18 facilitates the engagement of the detonator cord 16 with the shaped charges 14.

A method embodying the invention is practiced by positioning a foam core 10 adjacent a housing 24. One or more shaped charges 14 are inserted in one or more

recesses 12, and a detonator cord 16 is placed in engagement with the shaped charges 14. The foam core, detonator cord 16, and shaped charges 14 are then inserted into an open end of the selected housing to complete the perforating gun. In other embodiments of the invention, and open end 28 of the housing 28 is closed with a seal 30, the firing head 46 can be attached to the housing 28, and the firing gun assembly can be lowered into a well casing. The shaped charges 14 can be detonated to perforate the well casing as previously described. Where the foam core 10 is formed with two or more core sections 20, each core section 20 can be placed adjacent to the housing 24, the detonator cord 16 can be placed within the hole 18, and the core section 20 can be positioned adjacent to each other to construct the foam core 10. The shaped charges 14 can be placed within the recesses 12 before or after the multiple core sections 20 are assembled into the foam core 10.

Embodiments of the present invention are readily adaptable to expand the length of the foam core 10 and the number of shaped charges 14 within the housing 24. After the foam core 10 is inserted within the housing 24, an additional foam core 10 retaining additional shaped charges 14 can be inserted into the housing 24 to extend the length of the original foam core 10. In this fashion, the total length of perforating charges within the housing 24 can be extended to any desired length. Moreover, embodiments of the present invention can provide flexibility in placing the shot orientation of the shaped charges 14, and in the size and configuration of the shaped charges used. If desired, each shaped charge 14 can be oriented to point the same direction or in a selected orientation within the housing 24. For example, all of the shaped charges 14 could be directed downwardly for use in low side

perforating operations, or could be oriented in another desired direction or combination of directions.

Embodiments of the present invention can provide flexible, inexpensive shaped charge retainers that can be quickly assembled to create a perforating gun. The structure permits the disassembly and reuse of the components, and readily permits the length of a perforating gun to be extended or reduced.

Although the invention has been described in terms of certain preferred embodiments, it will be apparent to those of ordinary skill in the art that modifications and improvements can be made to the inventive concepts herein without departing from the scope of the invention. The embodiments shown herein are merely illustrative of the inventive concepts and should not be interpreted as limiting the scope of the invention.

CLAIMS

1. An apparatus for retaining a shaped charge, which is ignitable by a detonator cord, within a housing which can be lowered into a well, the apparatus comprising:

a foam core insertable within the housing;

a recess within said foam core for retaining the shaped charge in a selected position within the housing; and

a hole in said foam core for permitting engagement between the detonator cord and the shaped charge.

2. An apparatus as claimed in claim 1, further comprising a seal attached to the housing for isolating said foam core within the housing.

3. An apparatus as claimed in claim 1 or 2, wherein said foam core comprises first and second core sections in contact along a plane parallel to a longitudinal axis of the housing.

4. An apparatus as claimed in claim 1, 2 or 3, wherein the detonator cord is positioned within said hole.

5. An apparatus as claimed in claim 1, 2 or 3, wherein the detonator cord is substantially positioned outside of said foam core, and wherein said hole permits the insertion of the shaped charge therethrough to permit engagement between the detonator cord and the shaped charge.

6. An apparatus as claimed in any one of claims 1 to 5, further comprising a second foam core insertable within the housing at a position adjacent to said foam core.

7. An apparatus as claimed in claim 6, wherein said foam core and said second foam core each have shaped ends for relative engagement therebetween.

8. An apparatus as claimed in any one of the preceding claims, further comprising protrusions

attached to said foam core for contacting the housing.

9. A perforating gun for retaining shaped charges which are ignitable by a detonator cord, and a firing had, the perforating gun comprising:

a cylindrical housing having an open end;

a foam core insertable within said cylindrical housing;

a plurality of recesses within said foam core each recess for retaining a shaped charge in a selected position within the housing;

at least one hole in said foam core for permitting engagement between a detonator cord and the shaped charges; and

a seal attached to said housing for isolating said foam core within said housing.

10. A gun as claimed in claim 9, further comprising a second foam core insertable within said housing at a location adjacent to said foam core.

11. A gun as claimed in claim 10, wherein said foam core and said second foam core each have shaped ends for relative engagement therebetween.

12. A gun as claimed in claim 9, 10 or 11, wherein said foam core comprises first and second core sections in contact along a plane parallel to a longitudinal axis of said housing.

13. A gun as claimed in claim 9, 10, 11 or 12, wherein said foam core has an exterior surface which substantially conforms to an inner wall of the cylindrical housing.

14. A gun as claimed in any one of claims 9 to 13, further comprising an aperture through said housing at a position proximate to said housing end, and further comprising a pin engaged with said aperture for retaining the firing head in engagement with said housing.

15. A method of retaining a shaped charge, which

is ignitable by a detonator cord, within a housing having an open end, the method comprising:

positioning a foam core adjacent the housing, the inner foam core having a recess for retaining a shaped charge and having a hole for permitting engagement between the shaped charge and a detonator cord;

inserting a shaped charge in said foam core recess;

placing a detonator cord in engagement with the shaped charge through the hole; and

inserting said foam core, detonator cord and shaped charge into the open end of the housing.

16. A method as claimed in claim 15, further comprising the step of sealing the open end of the housing to isolate the foam core within the housing.

17. A method as claimed in claim 15 or 16, further comprising the step of inserting an additional shaped charge in a recess within said foam core so that the shaped charges face in different directions.

18. A method as claimed in claim 15, 16 or 17, further comprising the steps of lowering the housing into a well and of activating the detonator cord to fire the shaped charge.

19. A method as claimed in any one of claims 15 to 18, wherein said foam core comprising first and second adjacent foam sections, and said hole is substantially within said foam core, and further comprising the step of placing the detonator cord in said hole before said second foam section is placed adjacent to said first foam section.

20. A method as claimed in any one of claims 15 to 19, further comprising the step of inserting a second foam core adjacent to said foam core within the housing.

21. An apparatus for retaining a shaped charge in a housing, the apparatus comprising:

a body member, insertable into a housing, which member has features of shape for retaining a shaped charge and for enabling a detonator cord to be engaged with such a retained shaped charge.

22. A perforating gun for use in a wellbore and including a shaped charge, a detonator cord and an apparatus as claimed in claim 21.

23. An apparatus for retaining a shaped charge within a housing substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

24. A perforating gun substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

25. A method of retaining a shaped charge within a housing substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

The Patent Office

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Application No: GB 9625237.4 **Examiner:** R C Squire
Claims searched: all **Date of search:** 17 February 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F3A

Int Cl (Ed.6): E21B; F42B; F42D

Other: Online:WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 0686530	GULF (see particularly fig.16)	21,22
X	GB 0677824	SCHLUMBERGER (see particularly page 2 line 73 to page 3 line 34)	21,22
X	US 4253523	IBSEN (see particularly col.5 lines 37-40)	21,22
X	US 4191265	BOSSE-PLATIERE	1,15,21 at least
X	US 4140188	VANN (see particularly fig.4)	21,22

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.